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# Assessment of Nickel and Chromium Release from Various Commercial Stainless-Steel Crowns (An In Vitro study)

**Rusal saad ahmed**

M.Sc. pedodontics
Department of pediatric and preventive dentistry/ collage of dentistry/ University of Tikrit

## Abstract

Prefabricated stainless steel crowns (SSCs) are one of the most common dental devices used to restore primary molars which are severely damaged or endodontically treated and as an abutment tooth for a space maintainer. The use of preformed crowns for primary tooth restoration reduces treatment time and number of visits to clinics. The chemical composition is 65–73% iron, 17–20% chromium, 8–13% nickel and less than 2% manganese, silicon and carbon.The frequent use of preformed crowns has led to concerns that heavy metals in the crowns could be released into the oral cavity and accumulate in the body. The purpose of this study was to determine how much nickel and chromium were released into artificial saliva by commercially available SSCs. Thirty samples of second primary lower molar SSCs were utilized, and they were split into three groups: group 1- Nichro SSC (China)-10 crowns, group 2-Kids crown (Korea)-10 crowns, group 3-3M™ ESPE™ SSCs (USA)-10 crowns. During the test, ten crowns from each group were placed in centrifuge tubes on a plastic platform. Using a flame-type atomic absorption spectrophotometer, the nickel and chromium levels of the artificial saliva samples taken within each tube following the removal of crowns and the control samples at the end of days 1, 7, 14, 21, and 28 were all determined. (GBC 932 plus, Australia). The amount of nickel and chromium released over a 28-day period across the three groups was estimated using two-way analysis of variance and pairwise comparison. The release of both nickel and chromium metal ions was observed in the three groups. However, there was no significant difference in the nickel and chromium release from SSCs among the three groups tested.

**Keywords:** Stainless Steel Crowns (SSCs); Nickel Release; Chromium Release; Artificial Saliva; Pediatric Dentistry; In

Vitro Study; Metal Ion Release; Biocompatibility; Corrosion; Atomic Absorption Spectrophotometry.

## Introduction

Early childhood caries of deciduous teeth, which affects infants and young children, is one of the most prevalent issues in pediatric dentistry. These dental cavities result in tooth structural deterioration linked to nutritional issues and an unbearable appearance for kids. The most common way to repair and maintain the remaining tissue of severely damaged teeth is using stainless steel crowns (SSC) and covering the damaged crowns of the teeth [5]. They are ready-made full-crown restorations, available in kits. Each kit has several crown sizes dedicated to a particular deciduous molar. The crown is then placed according to the manufacturer's instructions by cementing it on the tooth with luting cement. The accomplishment of a full-crown restoration with a long-term survival rate, the potential to restore teeth with extensive destruction, teeth following endodontic treatment, or teeth with developmental disorders of the tooth's hard tissues are all benefits of this type of restoration [16]. In addition to the benefits of SSCs, there are several limits associated with the utilization of these crowns due to The electrochemical corrosion phenomenon occurs in the oral cavity, resulting in degradation of the alloy as a result of enzyme activity, microbes, heat and chewing, in such environment, corrosion causes release of metals [12].

The term stainless steel refers to iron and carbon alloys that incorporate chromium, nickel, manganese, and potentially additional metals to enhance their qualities and confer a stainless quality to the steel. The stainless steel is strong, resilient and malleable. The thickness of the metal is 0.2 mm in SSCs and does not require an excess thickness to obtain clinical acceptability [2].

In pediatric dentistry, metals and alloys are utilized to fabricate space maintainers, stainless steel crowns (SSCs), and braces. Even though SSCs are being used more frequently, little is known about how they corrode and release metals, particularly nickel and chromium [8].

Proteins, electrolytes, hormones, and other elements that are occasionally found in blood make up the diverse composition of human saliva. The oral cavity's temperature, the pH fluctuations, and the foods consumed create an unpleasant environment for metal instruments in the mouth [13]. Numerous studies have demonstrated that stainless steel alloys near saliva display signs of corrosion and surface change, which reduces their biocompatibility and releases metallic ions, which may contribute to fatigue. Metal ions that are potentially released from the stainless steel alloy include Cr, Fe, and Ni [17]. The use of SSC for deciduous teeth has increased the concern about the release of heavy metals into the oral cavity due to corrosion [4]. Nickel is more prevalent among the discharged metals and can cause contact allergies and sensitivity reactions [18]. DNA harm has reportedly been linked to stainless steel alloys [16]. DNA can change even at non-toxic nickel amounts [15]. Additionally, sensitivity to nickel around the oral cavity is another common problem Therefore, this study set out to determine how much nickel and chromium were released into fake saliva by commercially available SSCs [10].

## Materials and Methods

Thirty samples of second primary lower molar SSCs were utilized. Three groups of SSCs were used in this investigation group

The first group Nichro SSC (China)-10 crowns

The second group Kids crown (Korea)-10 crowns

The third group 3-3M™ ESPE™ SSCs (USA)-10 crowns.

Making a saliva-simulation medium• 0.14 grams of sodium chloride, or NaCl

0.42 grams of potassium chloride, or KCl

0.26 g of disodium anhydrous phosphate (NaH2 PO42 H2O)

0.017 g of sodium sulfide (Na2S,9H2O)

0.35 g of urea (CO (NH2)2)

350 milliliters of deionized distilled water

Albumin (albumin bovine fraction V)

## Methodology

The artificial saliva's pH was measured using a pH meter, and it was adjusted to 6.75 ± 0.05 by incorporating 1 N of sodium hydroxide or 1 N hydrochloric acid as needed. The test involved the placement of ten crowns from each group in centrifuge cylinders on a plastic platform; each crown was kept in its own tube. To stop the solution from evaporating, each tube was securely sealed. As controls, two tubes with just artificial saliva and no crowns were utilized. Every tube was kept in an incubator at 37°C. Crowns were taken out of each tube at the end of the 1 day, and they were then put in new tubes with freshly made artificial saliva for an additional seven days. The crowns were taken out of each tube at the end of the 7 day and put in a fresh set of tubes containing artificial saliva that had just been made. Every tube was kept in an incubator at 37°C for a week, and the process was repeated at the end of days 7, 14, 21, and 28. Using a flame-type atomic absorption spectrophotometer, the nickel and chromium levels of the artificial saliva samples taken within each tube following the removal of crowns and the control samples at the end of days 1, 7, 14, 21, and 28 were all determined. (GBC 932 plus, Australia).

## Statistical analysis

The amount of nickel and chromium released over a 28-day period across the three groups was estimated using Pairwise comparison and two-way analysis of variance

## Results

All three of the examined SSC groups exhibited the release of both nickel and chromium ions. Statistical tests are presented in tables 1 through 6.

**Table 1: Descriptive statistics (median, mean, SD, maximum, minimum, and sample size) of the amount of chromium variable across different time points (Day 1–Day 28) in four experimental groups.**

| group | n | Min | max | mean | SD | median |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| Day1 | 10 | 0.2 | 0.3 | 0.235 | 0.0277 | 0.235 |
| Day7 | 10 | 0.45 | 0.56 | 0.522 | 0.0416 | 0.53 |
| Day14 | 10 | 0.28 | 0.35 | 0.317 | 0.0240 | 0.32 |
| Day21 | 10 | 0.20 | 0.25 | 0.223 | 0.0170 | 0.225 |
| Day28 | 10 | 0.186 | 0.276 | 0.255 | 0.0326 | 0.2575 |
| 2 | | | | | | |
| Day1 | 10 | 0.2 | 0.3 | 0.258 | 0.0346 | 0.24 |
| Day7 | 10 | 0.43 | 0.52 | 0.472 | 0.0410 | 0.47 |
| Day14 | 10 | 0.22 | 0.33 | 0.253 | 0.0270 | 0.253 |
| Day21 | 10 | 0.20 | 0.21 | 0.208 | 0.0075 | 0.208 |
| Day28 | 10 | 0.198 | 0.230 | 0.216 | 0.0120 | 0.221 |
| 3 | | | | | | |
| Day1 | 10 | 0.2 | 0.3 | 0.249 | 0.0306 | 0.245 |
| Day7 | 10 | 0.46 | 0.53 | 0.493 | 0.0386 | 0.495 |
| Day14 | 10 | 0.23 | 0.30 | 0.262 | 0.0270 | 0.255 |
| Day21 | 10 | 0.20 | 0.24 | 0.217 | 0.0140 | 0.215 |
| Day28 | 10 | 0.192 | 0.230 | 0.208 | 0.0140 | 0.210 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | | | | | | |
| Day1 | 2 | 0 | 0 | 0 | 0 | 0 |
| Day7 | 2 | 0 | 0 | 0 | 0 | 0 |
| Day14 | 2 | 0 | 0 | 0 | 0 | 0 |
| Day21 | 2 | 0 | 0 | 0 | 0 | 0 |
| Day28 | 2 | 0 | 0 | 0 | 0 | 0 |

**Table 2: Descriptive statistics (median, mean, SD, maximum, minimum, and sample size) of the amount of nickel release across different time points (Day 1–Day 28) in four experimental groups**

| group | n | Min | max | mean | SD | median |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| Day1 | 10 | 0.5 | 0.5 | 0.48 | 0.05 | 0.50 |
| Day7 | 10 | 0.70 | 0.80 | 0.75 | 0.04 | 0.74 |
| Day14 | 10 | 0.47 | 0.56 | 0.51 | 0.03 | 0.52 |
| Day21 | 10 | 0.40 | 0.46 | 0.44 | 0.02 | 0.43 |
| Day28 | 10 | 0.330 | 0.414 | 0.37 | 0.03 | 0.36 |
| 2 | | | | | | |
| Day1 | 10 | 0.4 | 0.5 | 0.47 | 0.05 | 0.45 |
| Day7 | 10 | 0.67 | 0.75 | 0.71 | 0.03 | 0.71 |
| Day14 | 10 | 0.50 | 0.54 | 0.52 | 0.02 | 0.52 |
| Day21 | 10 | 0.40 | 0.46 | 0.43 | 0.02 | 0.44 |
| Day28 | 10 | 0.318 | 0.418 | 0.38 | 0.05 | 0.36 |
| 3 | | | | | | |
| Day1 | 10 | 0.4 | 0.6 | 0.50 | 0.07 | 0.50 |
| Day7 | 10 | 0.66 | 0.72 | 0.70 | 0.02 | 0.70 |
| Day14 | 10 | 0.44 | 0.56 | 0.49 | 0.04 | 0.49 |
| Day21 | 10 | 0.38 | 0.43 | 0.41 | 0.02 | 0.40 |
| Day28 | 10 | 0.314 | 0.405 | 0.36 | 0.04 | 0.36 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | | | | | | |
| Day1 | 2 | 0 | 0 | 0 | 0 | 0 |
| Day7 | 2 | 0 | 0 | 0 | 0 | 0 |
| Day14 | 2 | 0 | 0 | 0 | 0 | 0 |
| Day21 | 2 | 0 | 0 | 0 | 0 | 0 |
| Day28 | 2 | 0 | 0 | 0 | 0 | 0 |

**Table 3. Chromium Release (Means ± SE and ANOVA)**

| Day | Group1 mean±SE | Group2 mean±SE | Group3 mean±SE | P_ value |
|---|---|---|---|---|
| Day1 | 0.246± 0.009 | 0.259± 0.010 | 0.259 ± 0.014 | 0.72 ns |
| Day7 | 0.514± 0.013 | 0.472± 0.011 | 0.501± 0.008 | 0.4* |
| Day14 | 0.318± 0.008 | 0.249 ± 0.009 | 0.262 ± 0.007 | 0.01** |
| Day21 | 0.226± 0.005 | 0.209± 0.003 | 0.221± 0.004 | 0.15ns |
| Day28 | 0.258± 0.010 | 0.215 ± 0.004 | 0.210 ± 0.004 | 0.02* |

ns = not significant * = $p < 0.05$ ** = $p < 0.01$

This table shows the average chromium release in each group over various days, with standard error and overall statistical significance. Differences between groups are significant on Day 7, Day 14, and Day 28, while on Day 1 and Day 21 the differences are not statistically significant.

**Table 4. Nickle Release (Means ± SE and ANOVA)**

| Day | Group1 mean±SE | Group2mean±SE | Group3 mean±SE | P_ value |
|---|---|---|---|---|
| Day1 | 0.48± 0.05 | 0.47± 0.05 | 0.50 ± 0.07 | ns |
| Day7 | 0.75± 0.04 | 0.71± 0.03 | 0.70± 0.02 | ns |
| Day14 | 0.51± 0.03 | 0.52 ± 0.02 | 0.49 ± 0.04 | ns |
| Day21 | 0.44± 0.02 | 0.43± 0.02 | 0.41± 0.02 | ns |
| Day28 | 0.37± 0.03 | 0.38 ± 0.05 | 0.36 ± 0.04 | ns |

There were no statistically significant differences in the mean nickel release levels across all groups (Group 1, Group 2, and Group 3) at any time point (all p-values indicated as ns, meaning not significant).

**Table 5. Pairwise Comparisons of Chromium Release**

| Day | Comparison | Mean difference | SE | P-value |
|---|---|---|---|---|
| **Day1** | **G1-G2** | **-0.013** | **0.013** | **0.33ns** |
| | **G1-g3** | **-0.013** | **0.017** | **0.42ns** |
| | **G2-g3** | **0.000** | **0.018** | **0.99ns** |
| **Day7** | **G1-g2** | **0.042** | **0.017** | **0.03*** |
| | **G1-g3** | **0.013** | **0.015** | **0.39ns** |
| | **G2-g3** | **-0.029** | **0.014** | **0.05*** |
| **Day14** | **G1-g2** | **0.069** | **0.012** | **0.001**** |
| | **G1-g3** | **0.056** | **0.011** | **0.002**** |
| | **G2-g3** | **-0.013** | **0.010** | **0.22ns** |
| **Day21** | **G1-g2** | **0.017** | **0.007** | **0.07ns** |
| | **G1-g3** | **0.005** | **0.006** | **0.41ns** |
| | **G2-g3** | **-0.012** | **0.005** | **0.09ns** |
| **Day28** | **G1-g2** | **0.043** | **0.011** | **0.01*** |
| | **G1-g3** | **0.048** | **0.011** | **0.008**** |
| | **G2-g3** | **0.005** | **0.006** | **0.42ns** |

Direct comparisons between every pair of groups are shown in this table. On Day 7, Group 1 is significantly higher than Group 2, and Group 2 is lower than Group 3. On Day 14, Group 1 is significantly higher than both Group 2 and Group 3. On Day 28, Group 1 again shows significantly higher values compared to Groups 2 and 3. There are no significant differences between the groups on Days 1 and 21.

**Table 6. Pairwise Comparisons of nickle Release**

| Day | Comparison | Mean difference | SE | P_value |
|---|---|---|---|---|
| Day1 | **G1-G2** | **0.1** | **0.02** | **0.65ns** |
| | **G1-g3** | **-0.02** | **0.02** | **0.42ns** |
| | **G2-g3** | **-0.03** | **0.02** | **0.28ns** |
| **Day7** | **G1-g2** | **0.04** | **0.02** | **0.04*** |
| | **G1-g3** | **0.05** | **0.02** | **0.03*** |

| | | | | |
|---|---|---|---|---|
| | **G2-g3** | **0.01** | **0.02** | **0.72ns** |
| **Day14** | **G1-g2** | **-0.01** | **0.02** | **0.58ns** |
| | **G1-g3** | **0.02** | **0.02** | **0.31*** |
| | **G2-g3** | **0.03** | **0.02** | **0.19ns** |
| **Day21** | **G1-g2** | **0.01** | **0.01** | **0.44ns** |
| | **G1-g3** | **0.03** | **0.01** | **0.05*** |
| | **G2-g3** | **0.02** | **0.01** | **0.09ns** |
| **Day28** | **G1-g2** | **-0.01** | **0.02** | **0.61ns** |
| | **G1-g3** | **-.01** | **0.02** | **0.55ns** |
| | **G2-g3** | **0.00** | **0.02** | **0.99ns** |

Nickel release comparisons demonstrated that statistically significant differences occurred only at specific time points (Day 7, Day 14, and Day 21), primarily involving Group 1 versus Group 3. By Day 28, all groups showed similar release levels, suggesting stabilization over time.

## Discussion

Saliva is a low osmotic pressure solution that contains proteins, potassium, nitrogenous substances, sodium, chloride, and bioactonate [14]. In this investigation, SSCs were submerged in recently made artificial saliva that had albumin added as a protein. The study samples were incubated at 37°C to replicate the oral temperature. Since flame atomization is the most popular and practical atomization technique in atomic absorption spectrophotometry, it was utilized [6].

According to the findings, nickel and chromium metal ions were released at the end of days 1, 7, 14, 21, and 28. The nickel and chromium emission from SSCs did not, however, differ significantly amongst the three groups that were employed. Similar to the findings of the study on the biodegradation of nickel and chromium from space maintainers, there was an enhanced rate of release of metal ions chromium and nickel from SSCs in each of the groups at the conclusion of the seventh day, and the release of both metals gradually decreased with the increasing time period [1]. Although both metal ions were released in each of the three groups, there was no discernible variation in the amount of release between the groups on various days.

Ingested nickel compounds are thought to be largely harmless due to their sluggish absorption from the gastrointestinal tract, with discomfort being their predominant effect [3]. However, certain types of nickel may be acutely hazardous to humans when consumed orally at large doses (>0.5 g). Chromium only exhibits toxic effects when consumed in extremely high concentrations (4–7 mg/kg). All three of the SSC groups employed in this investigation released nickel and chromium, which may not have harmful effects but will undoubtedly make allergic individuals more sensitive [15].

Microbial activity-induced corrosion has been known for many years. Metal alloys submerged in aquatic environments are known to corrode due to microorganisms [9]. Metal surfaces are corroded by acidic waste products produced by bacteria and microorganisms. Therefore, the biodegradation of metals from stainless steel is also caused by microbial causes, which may result in a considerable release of nickel and chromium. [11]. However, this study only employed artificial saliva that was kept at a consistent pH and temperature; it was not based on the degradation of metal brought on by microbial causes.

## Conclusion

Despite SSCs' widespread use among pediatric dentists, not much research has been done on the crowns' side effects. To improve our understanding of SSCs and assess their safe use in pediatric patients, more research on the extended release of these ions in both in vitro and in vivo settings is therefore required.

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